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SIR GEORGE CAYLEY'S NAVIGABLE BALLOON.

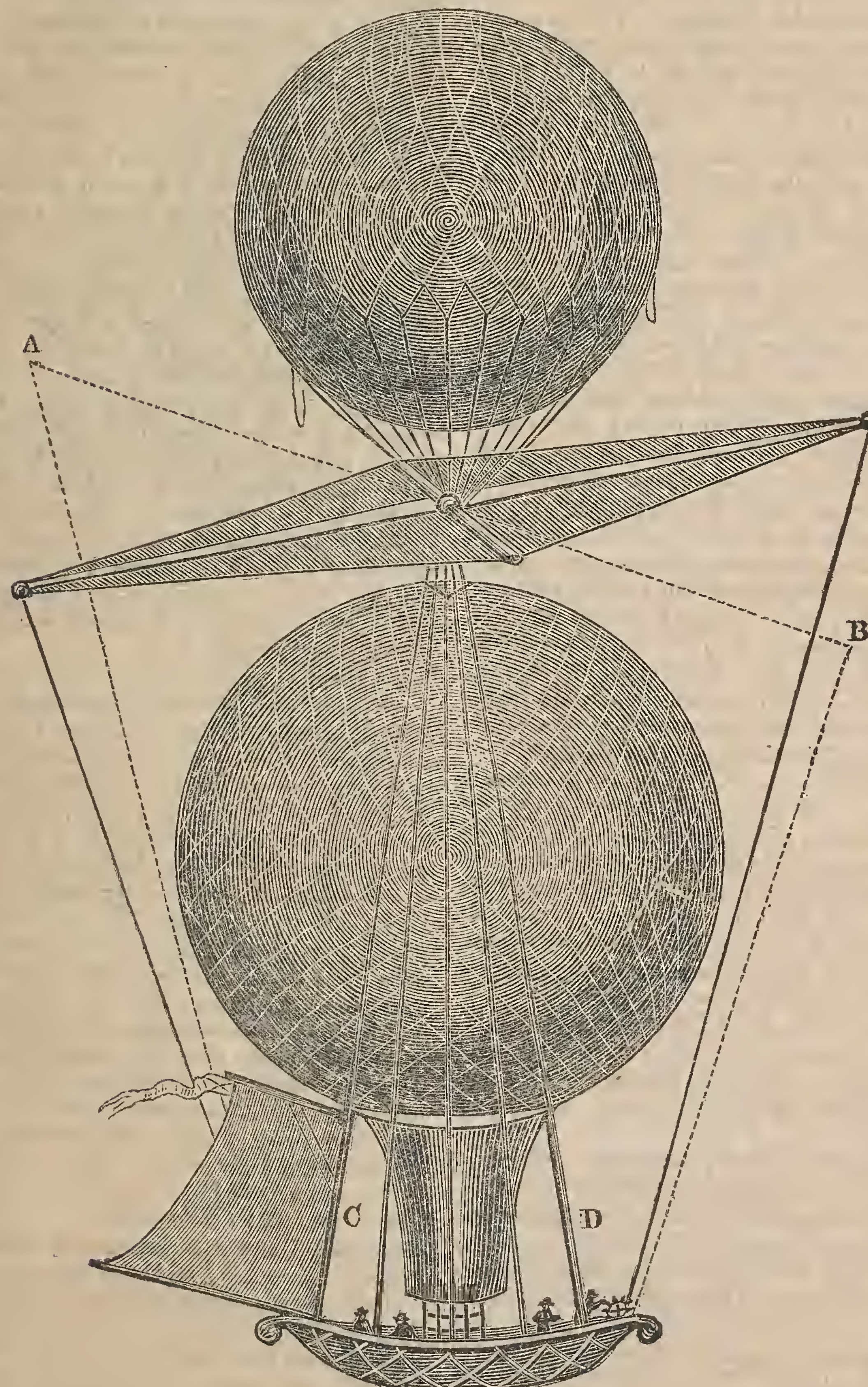

Plate 1.

PRACTICAL REMARKS ON AERIAL NAVIGATION. BY SIR GEORGE CAYLEY, BART.

Sir,—Permit me, through the pages of the *Mechanics' Magazine*, which widely circulates among the efficient mechanics of this engineering age, to call their attention to a subject of great national interest, and one that offers perhaps the most difficult triumph of mechanical skill* over the elements man has to deal with—I mean the application of aerial navigation to the purpose of voluntary conveyance. There seems to be, if we may judge by the scattered notices in the public journals, a revived attention to this subject, not only in this country, but also in France and America: the experiments that have been made, and the investigation which it has undergone, lie almost unconnected in the periodical publications of the last thirty years; and hence every new speculator on the possibility of steering balloons, takes up the subject merely on his own view; and as it requires much complicated calculation, as well as the utmost exertion of engineering skill, it is not surprising that we do not make much progress, especially when we consider the enormous expense of making experiments upon it on an *efficient scale of magnitude*.

Among others, five-and-twenty years ago, I paid considerable attention to the subject of aerial navigation, and collected or ascertained several of the leading points and laws of action that must be complied with to render any attempt respecting it successful. These were published in the *Philosophical Magazine* for 1816 and 1817, &c. I shall not, however, repeat much of what is there said, but proceed to state what I consider most conducive at present towards a final accomplishment of the aerial object in view.

In the first place, the enormous bulk of balloons, as compared with the weight they will sustain, causes the *difficulty* of impelling them, with sufficient speed to be of any utility, either by manual or engine power; and this *difficulty* is by many truly scientific persons considered as insurmountable, because they conceive that the bulk, which causes the resistance, must ever be commensurate with the weight of engine necessary to propel them by any species of waftage—and, consequently, as it will not do on a small scale, that it cannot on a large one. It is true, that it requires twice as much gas to sustain a 4-horse power engine as to sustain one of a 2-horse power (with their loads of fuel and water); but it is not true that the larger balloon, though perfectly similar in make to the smaller one, will, when driven through the air at the same velocity, meet with *double* the resistance—if it were so, the case of steering balloons would be hopeless, and on this mistaken ground many think it a vain attempt. This idea, resting at the very threshold of the invention, and which seems to present an insurmountable barrier, when probed and fully investigated proves to be false, and the investigation leads to an immutable law of proportion between the resistance and the capacity to carry weight or engine-power, which, on a very large scale, promises the most satisfactory result.

If balloons of the respective diameters of one and two, both being spherical, be driven through the air with equal speed, the resistance will be as the *surfaces* opposed to the air, and the surface of the largest will be four times greater than that of the smaller, and hence it will require *four* times the engine force to keep up the velocity; but the quantity of gas contained in the larger balloon is *eight* times greater than that in the smaller, hence it could sustain eight times as much engine-power; but four times that power would keep up the required velocity, and hence it could carry a cargo of the weight of its engine, and yet keep pace with the smaller balloon. The simple terms of the case are, that the surfaces (and hence the resistances) increase as the *squares* of the diameter of the balloon; whereas the capacity to contain gas (and hence the supporting power) increases as the *cubes* of the diameter.

From this *unquestionable* law it follows, that if similar shaped balloons vary in diameter as the numerals, 1, 2, 3, 4, 5, &c., the resistance they will meet with in the air, at the same velocity, when compared to the weight (or engine-power) they will sustain, will be as 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$,

* This letter was commenced about four months ago; I am extremely glad to see how much this subject has grown upon public attention since that time, and how many excellent notices of it are contained in the last three monthly numbers of your Magazine up to September, which I have just received.

$\frac{1}{4}$, &c. This is a most important fact, and proves that as the law of relative diminution to resistance is *unlimited*, there must ever be, *theoretically*, some bulk in which any species of first mover, however sluggish in proportion to its weight, would find itself suspended, and its power adequate to propel that bulk with the velocity required. So far for the *principles* in action; let us now come to the real practical limits and bearing of the case.

The first thing that presents itself to our notice is the choice of a proper material of which to form a balloon for the required purpose; and the properties are those of being perfectly air-tight, light, and strong. Silk and Indian-rubber varnish are thus indicated, and have long been used; but in the larger constructions, that are suggested by the previous investigation, the expense of silk would almost prove a bar to real use. The double-cotton Indian-rubber cloth, used by Mr. Macintosh in his manufacture of air-tight seats and cushions of various kinds, weighs very nearly 1lb. per square yard, and will just sustain a tension of 2,500lbs. per lineal yard, that is, if the yard of cloth were rolled up and used like a rope, it would sustain any weight less than 2,500lbs. Of course, if used flat, as a portion of the surface of a balloon, it would sustain tension to the same amount. This cloth, when made to adhere to an adjoining breadth by an overlap of one inch with the Indian-rubber varnish, is air-tight at the seam; and is to the full as strong in resisting tension as at any other part, as I have found by experiments carefully made for the purpose.

As we now travel by railroad pretty constantly at the rate of 20 miles per hour, aerial navigation, though offering a direct navigable ocean to every point of our globe, would scarcely be worth cultivating, if not practicable ultimately at least up to that speed.

To be able to sustain the form of the balloon, when driven against the air with that velocity, implies that the condensation within must press rather more than the resistance of the external air; but at that velocity, by the well-known laws of resistance, every square yard near the centre, facing the line of flight, will meet a resistance of about 29lbs.; and hence the condensation over the whole interior of the balloon must give 29lbs. pressure per square yard. More than this, balloons, to be really serviceable, must when at anchor, or by accident driven against obstacles, be able to resist the action of our most violent storms, which, according to Smeaton's table, go at the rate of 60 miles per hour, tearing up trees, and creating a pressure of 162lbs. per square yard.*

This cloth can just sustain 2,500lbs. per lineal yard; and hence, by calculating the forces, it follows that the extreme limit of size to which a spherical balloon made of it could safely be carried when occasionally condensed to meet our storms, whilst at anchor, or when compressed against objects casually by them, would be 60 yards in diameter.†

Let us not be startled at this deduction, for in practice we may use as much less as we find convenient; and it is a feature of very great importance in favour of aerial navigation, that such a slight fabric is capable of becoming a safe vehicle of support to so vast an extent—and here it should be remarked, when balloons are made of forms differing from the sphere, that where for any considerable length they approach, as in elongated spheroids, to a cylindrical form, the cloth will only sustain near the minor axis half the pressure or condensation it will sustain as when in a sphere of the same

* These calculations are based upon the resistance being in the ratio of the squares of the velocities; and that a velocity of 21 feet per second gives a resistance in air of 1lb. to the square foot.

† The whole lineal measure of the circumference (being, in round numbers, 188 yards, capable of bearing 2,500lbs. each), can bear 470,000lbs.; whereas the whole area of the great circle on which the pressure takes place, being 2,840 square yards with a pressure of 162lbs. on each, only amounts to 460,0 0lbs.

In speaking of condensing the gas in balloons, which is a new feature in them, it will be necessary to provide a safety outlet by bringing a wide pipe from them, and placing the end of it a few inches under water; a column of $3\frac{1}{2}$ inches of water would equal the condensation of 162lbs. per square yard. The escape of gas should be into a small empty balloon above the water, from which it can be pumped out at pleasure; the change of temperature in the climate also requires this structure. Eventually balloons will probably have a double casing, with common air, or, what would be safer, azote, pumped in between them. A small balloon to contain common air pumped into it, having a tube from it with its mouth a certain number of inches under water, and its bulk contained *within* the gas-balloon, would be the readiest way to meet all cases of condensation and expansion. With air-tight materials there would be no mixture of common air with the hydrogen, but this plan would require the materials to be perfectly so. To prevent danger from the fire of the engine, several wire-gauze divisions should be made in the chimney.

diameter; hence 30 yards would be the extreme limit of the shorter axis of an elongated spheroidal balloon made of this cloth.

As the netting, belting, or whatever means be adopted to enable the floating-power of balloons to sustain the burthens attached to them, must necessarily extend over more than half their surface, it would be best to complete the circuit, and thus add the strength of the netting to resist condensation, and fortify the cloth, especially near the shorter axis.

Condensation is a term that seems, and to a certain extent is, adverse to aerial navigation; but the whole condensation here required will only deduct 1lb. of buoyancy from every 120lbs. previously exerted by the gas, a sum too trifling to be of any consequence, and abundantly redeemed by the *firmness* it gives to whatever form it may be required to model balloons for obviating as much as possible the resistance of the air.*

The next consideration is the proper form of the balloon for this purpose; and here it is obvious, that to extend their length horizontally, and thus to diminish their cross-section, is the leading point of the investigation. This will be limited by the practicable extent to which the structure can be carried without incurring weakness, in respect to the preservation of form, or inconvenience in the mode of suspending the car or body from the balloon. Ships and boats range between three and six times the measure of their greatest cross-section; birds between two and four. When convenience has pointed out the limits that must guide us in making use of *length* to obviate resistance, the *form* of the balloon, to meet the least resistance within these limits, is naturally the next inquiry. Unfortunately even the sagacity of Newton has not been able practically to grapple with this very interesting and intricate question; and his beautiful theorem on this subject will not apply to any of our gross fluids, which wedge themselves up by accumulation after they have struck upon the resisting body, and have no free egress to make room for others. The Newtonian solid of least resistance has a prow concave near the anterior axis; and as air is more elastic than water, the prow, if we may use the term, of birds is also concave; whereas in fishes the prow, as in ships, is convex. In the absence of all good authority, I have proposed (at p. 400 of the *Philosophical Journal* for 1816) to copy the prow of the woodcock as there given by exact measurement. This bird was selected from its having frequently to pass 500 miles of sea at one flight; and because in its structure Nature seems to have united every contrivance to blend strength with lightness. The resistance of the air to its passage was the great obstacle to be overcome; and hence it is more than probable the best form (which, more than all the rest, would tend to the ease of the performance) has been selected also. It is about $3\frac{1}{2}$ times the length of its greatest cross-section.

The hinder portion of resisting solids is proved by experiment to be of as much importance as the prow; but as its office is to fill up the space, shielded from pressure for a time by the diverging momentum of the fluid driven off by the prow, any figure approaching to that of the cone answers the purpose tolerably well, if we may judge by the lengthened conical taper of the tails of fish; indeed it is a common expression among sailors, that a ship to sail well should have a "cod's head and a mackerel's tail."

We may rest contented to make our experimental balloon of an extended spheroidal form, and leave the rest to future improvement. The best form of ships remains in a great measure to be ascertained yet; although navigation has been bestowing wealth and comfort on mankind for so many ages under a rude approximation to it.

The next objects of inquiry are the power to be used in propelling the balloon, and the means of applying that power. Only two general modes have, I believe, ever been proposed by competent persons for this purpose. My friend Mr. Evans (see the *Philosophical Magazine*, for 1815, vol. xlvi., p. 321,) tried with success to steer a small Montgolfier balloon by suspending a large oblique surface beneath it, which caused the ascent to be oblique in the direction towards which the upper edge of the plain was pointed; when the fuel failed, gravita-

* The expense of using pure hydrogen gas points out the necessity of balloons being perfectly air-tight, and when used as permanent vehicles, and on the true scale of magnitude, they will probably be made of thin metallic sheets kept firm by condensation, with separate light bags of gas within.

tion made its return *obliquely* to the place from which it set out; had this plain been reversed when at the top of its rise, steerage towards the same point of the compass would have been effected in both cases by this sort of vertical tacking.

This movement implies the use of the fire-balloon; but it does not follow that the *whole* support must necessarily be given on that principle: suppose that two-thirds of the weight of the whole machine were suspended by a hydrogen-gas balloon, by any sufficient length of cordage (say it required from 50 to 100 yards), to ensure all danger from fire. Immediately above the car place a fire-balloon, likewise capable, when fully inflated, of supporting two-thirds the weight of the whole apparatus. When both balloons operated upon a large oblique inclined plain, with a power of ascension equal to one-third of the whole weight, it would render the oblique force very efficient in ascending; and when at the highest point of elevation the heated air is let off by the valve, and the plain reversed, one-third of the whole gravitation would give it an equally effective oblique descent. A machine on this construction would, on account of its progressive motion, obey a rudder, by which more exact steerage could be effected. It is certainly the most simple and least expensive way of primarily effecting the problem of steering balloons; but there is something unsatisfactory in being obliged thus to resort to such alternating heights and descents, implying such sudden changes of temperature, to say nothing of the devious and prolonged nature of the track, and the consequent waste of power. I send you a rough and hasty sketch of such a combination of balloons, having a large inclined plain suspended between them, capable of being pointed obliquely for either tack by cords from the car, as shown by the present position of the plain, and the dotted line A B, plate 1. The balloons are made in such proportion to each other as to be of equal power, their contents being as ten to four* very nearly. Several strong ropes should pass from the collected cordage of the upper balloon through the interior of the lower one, as exhibited by the dotted lines, and be made fast to a large hoop forming the top of the chimney; this is partly held up by the two light masts C and D, and forms the means of suspending the car from both balloons, as the cordage from the netting of the lower balloon is also collected on this hoop. From the hinder mast C a sail may be conveniently braced to either side, so as to act as a rudder, and thus preserve a steady course. It is necessary to have a long chimney in Montgolfier balloons, when *speed* is required, to give sufficient pressure within to balance the external resistance, this must be 75 feet long to balance the resistance of a balloon at 20 miles per hour; and is, no doubt, a great inconvenience in this mode of action. The balloon sketched is supposed to be 30 feet in diameter, with 10 feet of chimney, thus giving 40 feet of columnar height at the top of the balloon, which would create a pressure equal to the external resistance, at a velocity of about 14 miles per hour. I do not offer this as a finished model, but merely sufficient to exhibit the principles in a visible form.

Steam, or any mixture of it with heated air, does not offer much prospect of advantage in filling Montgolfier balloons, and if it did, it could only be used when the balloons were of enormous magnitude, so that the proportional diminution of surface and increase of thickness in the materials, had greatly diminished the condensing power of the external air with Indian-rubber cloth of 1lb. to the square yard, which would nearly absorb all the power of the 30 feet balloon I have specified, it would (according to some experiments I made, on cooling, with that cloth,) take about 100lbs. of coke per hour to supply its condensation of steam at the ordinary temperature of our atmosphere.

Let us now consider the more direct plan of steerage by the waftage of surfaces to which engine power is applied. Some persons doubt whether if such power can be conveniently suspended to balloons, it would be efficient, because there are not *two* fluids to work upon, as the water and air in the case of ships; but this argument does not apply since the introduction of the steam-boat, where the wind has no concern in the movement; and, indeed we might as well doubt whether the muscular power in the bird's wing is that which propels it forward, as doubt that engine-power,

* 27 ounces per square yard in hydrogen-gas; 11 ditto hot-air according to the French experiments on Montgolfier balloons.

if properly applied to balloons, will have a similar effect.

My friend Mr. Goldsworthy Gurney has just completed some steam-carriages, the boiler and engine parts of which weigh no more than 200 weight per horse-power;* the supply of coke and water will be about (10 coke, 60 water) 70 lbs. per hour—say 30 lbs. more for the constant quantity left in the fire-place and boiler, and we have each steam horse, with its load for an hour in the weight of 300 lbs. If we take loads for several hours, and use no means of saving water by condensation, which might readily be done, the loads per horse-power will stand thus:—

	Lbs.
For one hour	300
— two	370
— three	440
— four	510

This is at present our best practical result. In theory, however, it seems possible that we may obtain a horse-power at very high temperatures, and working by expansion only, at $15\frac{1}{2}$ lbs. of water and 10 lbs. of coke per hour. Lighter first movers than steam-engines may be discovered, and made applicable to propelling balloons; but let us take the case as our experience now places it.

Here, in fact, commence the real difficulties we have to contend with in rendering balloons serviceable to mankind; we have as yet only obtained the grounds of calculation, and thsee, when correctly followed up, place the result of the question not on any point of defective theory; but whether it is, or is not, practicable to construct them so as to be firm, air-tight, and manageable, when of dimensions far exceeding any experiments that have been hitherto tried, *we must be contented to give up balloons for purposes of locomotion altogether, or to attempt them on that scale of magnitude which a well-grounded calculation of their powers proves to be necessary.*

It cannot, however, be thought useless, boldly and unflinchingly to *investigate* the case, which, if practicable, offers us the floatage of an uninterrupted ocean from every man's door to any other point on the globe;—let not such a boon to our race be given up without a fair and vigorous effort to avail ourselves of it in our own age. To commence:—suppose a balloon be made of the Indian-rubber cloth of Messrs. Macintosh and Co., in the form of an elongated spheroid thirty yards in diameter, and three and a half times that measure in length: although this would in bulk bear a strong resemblance to a hundred-gun ship, yet it would fold up into a cubical case 10 feet every way; and when inflated, is only a hollow bag received into a boundless ocean, where bulk ceases to be an inconvenience,—calculation proves that a condensation of one part in 120, will give it firmness sufficient to resist storms without affecting its form; and the cloth is known to be air-tight under much more intense condensation: surely, then, we can scarcely doubt the possibility of making such a balloon, or of inflating it by pumping, with pure hydrogen-gas, setting aside at present all consideration of the *cost* of the experiment.

The weight of the materials may be estimated as follows:—

	Lbs.
Indian-rubber cloth at 1 lb. to the square yard	8540
Mr. Green's great balloon contains about 2000 cubic yards of gas; this balloon will contain 49,000; and if the weight of the other materials be taken in proportion to these numbers, we shall have for the netting	3360
The car	3000
The grapples and other matters	3425
	18325
Each cubic yard of hydrogen-gas gives 1·7 lb. of floatage; hence the whole power will be	85·255
From which deduct the 120th part for condensation	693
	84·562
And also the weight of the apparatus	18·325
There will remain as the free power of the balloon	66·237

* Mr. Avery's American rotatory-engine will probably be still lighter if the loss of power do not balance its simplicity of structure.

Or about $29\frac{1}{4}$ tons, which may be divided in any convenient proportions between the engine-power and its apparatus for waftage, the crew, and the cargo.

Before this can be done, it is necessary to have an estimate of the resistance of such a balloon when driven through the air at the velocity we propose to obtain. Extensive as this balloon seems to be, according to the best data, it could not be driven by the engines, &c. it could carry, at more than 17 miles per hour; and is better qualified to be driven at 14. It is extremely probable, however, that our data give the resistances of curved vessels considerably greater than is found to be the case in practice; but let us rigidly adhere to that which our present degree of information points out, and consider 14 miles per hour as the intended speed of our balloon. At this velocity there will be a resistance of 9 lbs. to the square yard when directly opposed to the current;—hence, as the greatest cross-section of this balloon contains 710 square yards, the direct resistance of such a surface would be 6390 lbs. Mr. Robins found that a sphere only meets with about one-third of the resistance of its great circle, being as 1 to 2·7; others have found it still less, but experiments are scarce on this subject. With a view to the present inquiry, I made a light case of papers, glued together over a true spheroidal mould, 18 inches long by 6 in diameter, and loaded it so as to fall through the air in the line of its longer axis. A circle of 6 inches diameter was then loaded till it fell with equal velocity, keeping perpendicular, to the line of its fall, the weight required to drag the flat circle with equal speed, side by side, through a fall of 30 feet, was 4·8 greater than that of the spheroid (of course the *whole* weight of each apparatus was thus the measure of the resistance.) The additional weights used to bring the circle to an equal velocity with the spheroid, were so arranged within similar cases, as to give equal resistance. This spheroid was just three times the length of its minor diameter; whereas the proposed balloon is $3\frac{1}{2}$ times longer than its breadth, which will materially diminish its resistance—and it may, therefore, be safely taken at not more than a sixth part of the resistance of its great circle,* and in this case the resistance of the balloon at the proposed velocity will be $\left(\frac{6390}{6}\right)$ or 1065lbs.—and as the speed at which this force must be supplied is 14 miles per hour, or 21 feet per second, it is equal to 1065 × 21, or 22365lbs. raised one foot high per second, which divided by 550, the number of pounds raised one foot high by a steam-horse, quotes the power required as that of rather less than 41 steam-horses, call it in round numbers a 40-horse power, provided it could be applied from a solid fulcrum on the earth; but whatever kind of waftage may be employed, there will be a loss of power by its acting upon a rare and also a receding medium.

For the sake of perspicuity, suppose that the surface employed to propel the balloon be equal to that of its great circle, then it will receive as much resistance (following the law of the squares of the velocity, and the resistance of the spheroid being one-sixth of that of the great circle) at about $8\frac{1}{2}$ feet velocity, as the balloon does at 21 feet; but before the wafting surface can give this resistance, it must go back with $8\frac{1}{2}$ feet more speed than the balloon goes forward, so that the engine-power is working at a velocity of $(21 + 8\frac{1}{2})$ $29\frac{1}{2}$ feet per second, and this requires the power to be increased as 21, the former velocity, is to $29\frac{1}{2}$, or from a 40 to a 57 horse-power. Let us, then, consider our balloon as requiring, in round numbers, a 60-horse power.

The weight of the engine at 510lbs. per horse-power, with a load of fuel and water for four hours, will be 30,600lbs., which deducted from the 66,237, leaves 35,637lbs. of free floatage. Suppose the machinery for waftage to weigh as much as 13,000lbs., then there would still remain 22,637lbs. to convey passengers or cargo, say 100 men and their ordinary goods, or 10 men and a cargo of 21,000lbs.—about 9 tons.

This estimate was made on the plan of the direct waft backwards, merely for the sake of being more readily followed in its

* Mr. Tredgold, at p. 330 of his excellent work on the steam-engine, gives us all the particulars of the *James Watt* steam-boat, the length of which is to its greatest cross-section under water, as 5·7 to 1; and when the power which its engines can supply at the velocity, the paddles move with in still water is taken as a criterion of its only opposing force, the resistance, it does not appear to be more than one-sixteenth part of what the cross-section would receive. Hence we are probably allowing a much greater resistance to our balloon than on a large scale it will receive.

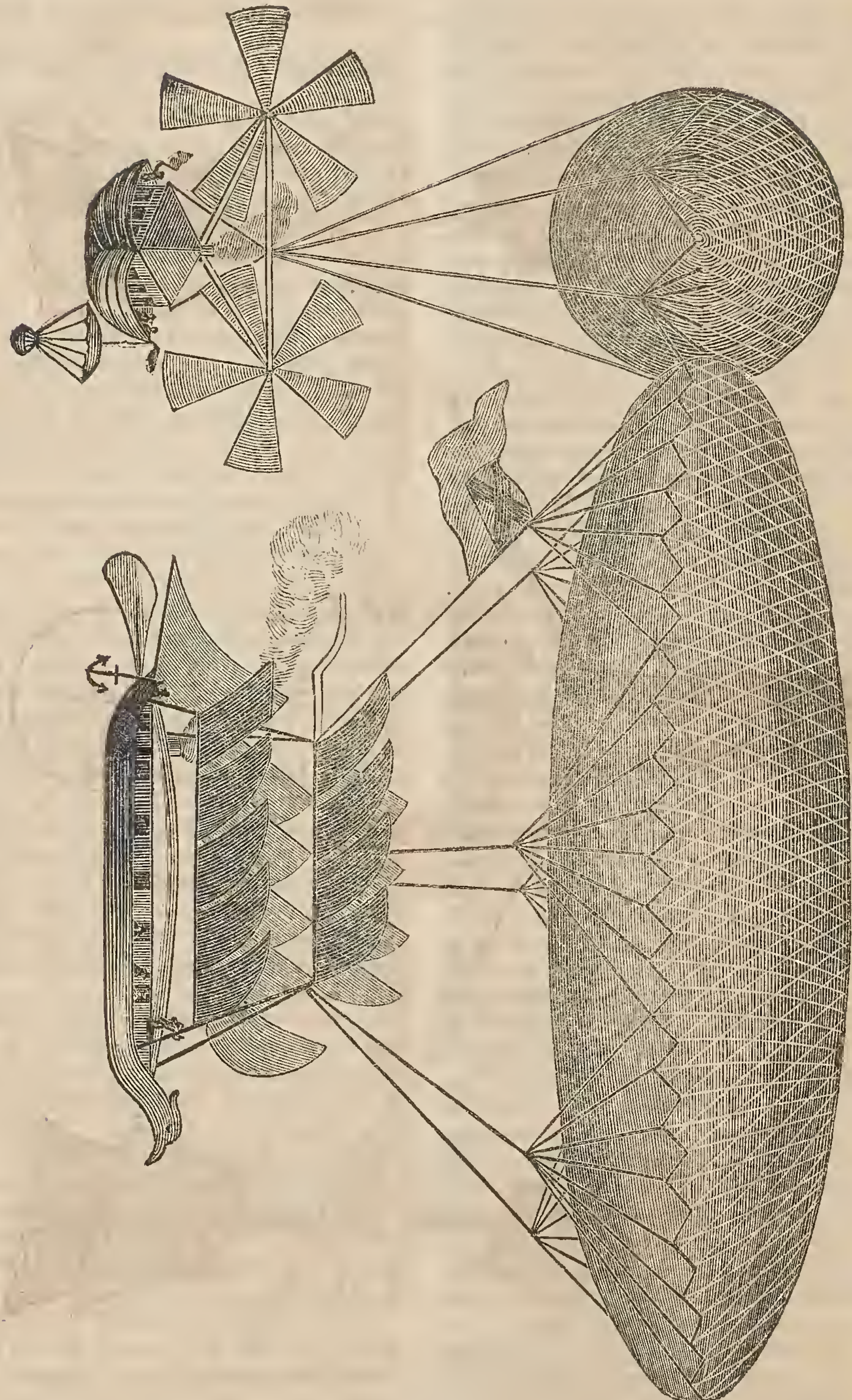

Fig. 1.

Fig. 2.

Plate 2.

various steps; and to avoid rendering the case intricate by adverting to that resolution of forces which takes place in oblique waftage, as in the wings of birds, the fins and tails of fishes, and in that which I am about to notice as applicable to our purpose.

It appears from the experiments of the French Academy, on the resistance of water at acute angles, corroborated by

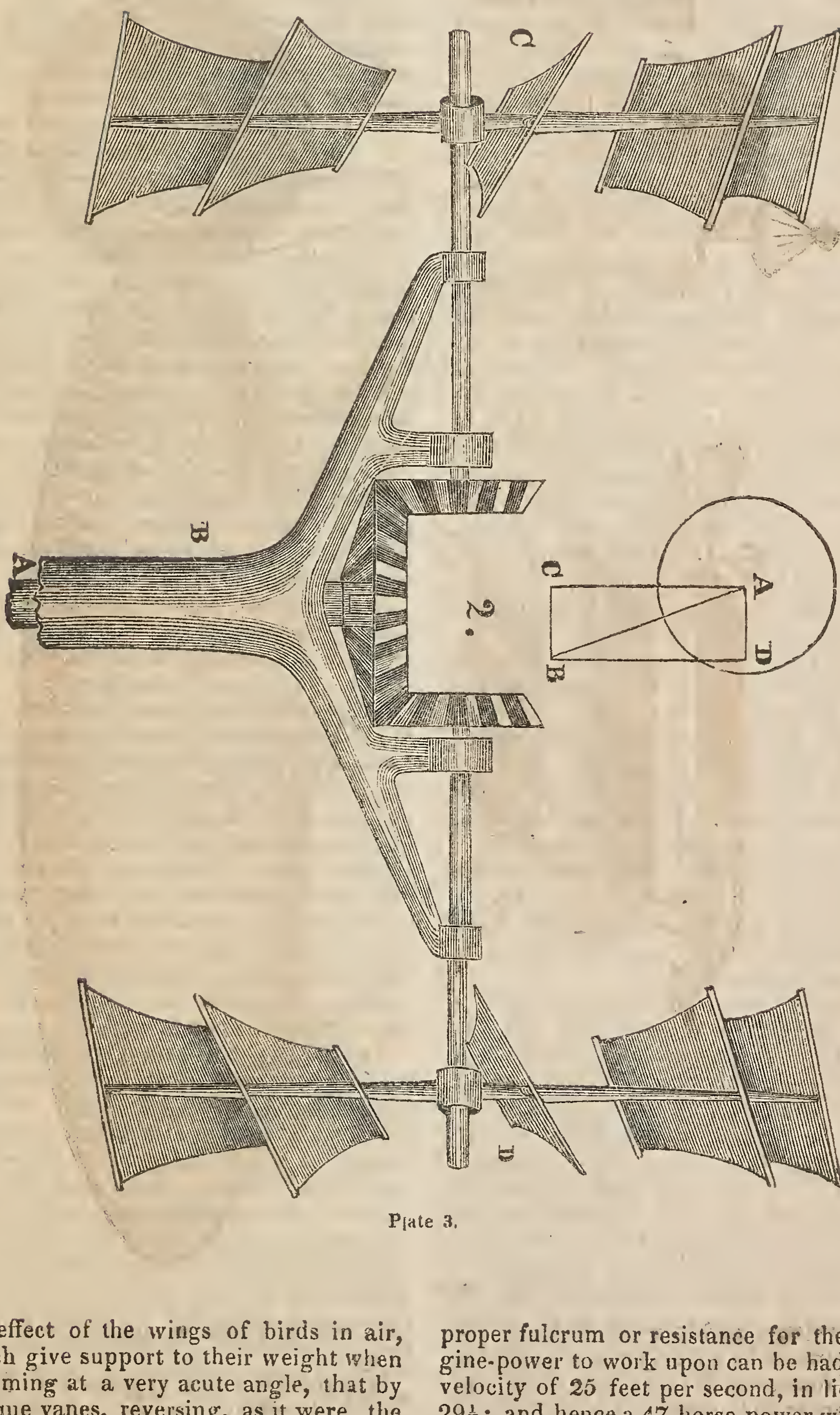

Plate 3.

the effect of the wings of birds in air, which give support to their weight when skimming at a very acute angle, that by oblique vanes, reversing, as it were, the action of the sails of a wind-mill, the proper fulcrum or resistance for the engine-power to work upon can be had at a velocity of 25 feet per second, in lieu of $29\frac{1}{2}$; and hence a 47-horse power will be sufficient for our purpose—in round num-

bers, say a 50-horse power in lieu of the 60-horse power on the former plan. This cannot be proved without a complicate diagram, and an explanation that would obtrude too much upon your pages, and most probably on the patience of your readers on the present occasion.

This will enable us either to add 5,000 more to the cargo, or, by using a 60-horse engine, to go with more speed.

Many persons erroneously suppose that any propelling force of waftage, when acting in the direction of the *car*, will not tend to propel the *balloon* above it. Let A, fig. 1, plate 3, be a balloon; let B be the position of its car, propelled beyond its centre of suspension, A, by any given power of waftage. Draw A C perpendicular, and C B parallel to the horizon; and let these lines be made in the same ratio to each other as the weight of the car is to the propelling power; then the line A B will represent the whole action of the car upon the balloon. Draw A D and B D respectively parallel to the two former lines; and as the floatage of the balloon is equal to the weight of the car, B D will as truly represent the floatage as A C does the weight; and, as the propelling power is, as soon as the speed becomes uniform, equal to the resistance, being the cause and measure of it, A D must as truly represent the resistance as its equal C B does that of the propelling power. In this position, then, all the powers are balanced in equilibrio; but there will be no resistance till the balloon has the velocity necessary to generate it, and this it finds at the same speed in the line A D, as if it were moving along its equal C B.

I will here take advantage of the same diagram to observe, that if a balloon be supposed to be at anchor in a gale of wind, by the car being secured to the ground, and the line A D be taken to represent the force of the wind, and B D the power of floatage, then A B will be the position the cordage will fall back to. The resistance to the prow of the balloon in question, at a hurricane of 60 miles per hour, would be about 20,000lbs.—deducting the car then on the ground, its floatage would be about 63,000—so that it would fall back about one part in three, which are the proportions purposely taken in the diagram, in order to prove that permanently-filled balloons would ride out storms when properly secured, without the danger of being driven to the earth and damaged.

Some persons are, however, disposed to strike at the root of all discussion as to steering balloons, by affirming that no waftage can propel bodies suspended in one and the same element in which the waftage takes place. These persons I will refer to p. 172 of *Nicholson'e Chemical Journal* for 1809, where they will find a description of a small machine, which they can make for themselves in a few minutes, that will elevate its own weight from the table to the ceiling, *merely by the waftage it creates.* The machine I have there described is a mere toy, but the *principle* on which it acts is capable of the most powerful and extensive application. I send you a view of its application to driving balloons, copied from a paper of mine at p. 81 of the *Philosophical Magazine* for 1817 (see plate 2, fig. 1), where there is likewise given a side elevation of a balloon with oblique wing waftage (fig. 2). The former by vanes revolving on an axis, the other by the heeling up and down of the surfaces in a reciprocating action, as in the bird's wing.

There is in one of the early volumes of the *Philosophical Transactions*, an account of propelling a boat with considerable velocity by men working this sort of waftage against the air; but I should prefer trying the more uniform action of the oblique vanes. More than one may be used on the same axis; and they may be so constructed as readily to apply their power, either to propel or retard, elevate or depress, as occasion may momentarily require. This will be obvious on inspecting fig. 2, plate 3.

Let the power of the engine communicate opposite movements to the reversed sets of fliers, C and D, through the cylindrical shaft A, and the wheels connecting them; the whole free power of the waftage will act in the line of their axis of motion. Conceive this axis to be moved into any position with respect to the horizon, by turning the hollow mast B (by which, through a suitable collar or socket the apparatus is supported from the car), and the balloon will be propelled accordingly. In the balloon we have been estimating, the four sets of such fliers would have to be 10 yards in mast or radius; and each sail would contain 30

square yards of surface. The figure given is intended merely to explain the principle of this action in the most distinct manner. In practice, this fabric, to unite strength with lightness, would be braced like the masts and sails of a boat; and its main strength derived from the ropes or metallic rods forming three braces.

Communicating centrifugal force to air by means of a hollow drum and fans worked by the steam-engine, is another means of getting a propelling power conveniently applicable in every direction that may be required; for by having a moveable mouth-piece, from which the air escapes, the re-action will always be in the opposite direction. Though convenient in this respect, it is too wasteful of power to be used for balloons, unless for small experimental purposes. Many other considerations remain untouched, upon; but I have already obtruded too much upon your pages with these dry details. The *subject*, however, is one of great interest, not merely in a mechanical point of view, but as to its stupendous effects on mankind at large; civilisation and, I trust, *perpetual peace* are in its train of consequences.

To such as have honoured me by wading through the train of this investigation, I will beg to remark, that they must not blame me for *wilfully* introducing such acres of cloth to their notice. Calculation from well-known data proves that balloons can only be driven with sufficient speed to be useful on the scale of magnitude I have pointed out. Let the question be put where it truly rests, whether such fabrics *can* or *cannot* be made and managed. The case is one evidently too great for individuals to make efficient experiments upon; and I am glad to see that some of your correspondents have recommended a subscription purse, and I hope that plan may be followed up. I proposed this in the year 1817, in the following terms (page 28, vol. 1., *Philosophical Magazine*):—

"We, the undersigned parties, enter into the following subscription for the purpose of ascertaining how far the principle of balloons supporting heavy burthens in the air may be made useful as a means of conveyance.

"No person to be called upon for his subscription money till at least 1000*l*. be subscribed for.

"When the subscription has reached this amount, an annual Committee of seven of the subscribers to be elected. Every subscriber of 1*l*., and of less than 5*l*., to have one vote. Subscribers of 5*l*. to have two votes; and subscribers of larger sums to have one additional vote for every additional 5*l*. they subscribe.

"No experiments to be undertaken but by order of the Committee, who may call in the advice of such civil engineers as they chose to consult.

"An annual report of the application of the funds, and the result of the experiments made, to be printed for the use of the subscribers.

"These regulations being the basis on which the subscription is made, cannot be altered; but subsequent rules not militating against these, may be entered into at a general meeting of the subscribers expressly convened for the purpose."

The late Mr. Lovel Edgeworth immediately before his death became a subscriber of 50*l*. towards this fund, which his deservedly celebrated daughter subsequently offered to make good. Mr. Evans also became a subscriber; but the age was not then ripe for the subject—steam-boats were in their infancy, and railroad velocity unknown; twenty miles an hour then seemed monstrous and chimerical; now our only fear is that balloons will not have speed enough to satisfy our locomotive mania. I must not mention the respected name of Edgeworth without stating that he puts in a previous claim to that of Mr. Evans (see *Philosophical Magazine*, for 1816, p. 185,) to the principle of steering balloons on the tacking plan by the use of the inclined plain. He appears to have communicated the plan to Monsieur Montgolfier in the year 1782. Mr. Evans is, however, the first person that has proved the invention experimentally.

Balloons, as has been long ago observed, ought not to be made all in one, but have several departments for the gas, like "the stomach of a leech,"—and should the promoters of aerial navigation get up a purse and combine their efforts during the present season, I should strongly recommend that Mr. Green's large balloon, and that gentleman's great experience and skill, be put in requisition; that two other of the largest balloons that are in town be packed at opposite sides of this large one, under one netting made in compartments for the purpose; the whole free floatage may then be ex-

pected to be equal at least to 23 men; let the crew be Mr. Green and his assistant, and let the weight of twenty-three men, say 3400 lbs., be occupied by the lightest possible tubular boiler and high-pressure steam-engine of 5-horse power, which, no doubt, would be got up with a 4-hours' load, at 2500lbs., leaving 1100 lbs. as the weight of the fliers for waftage. This might be expected to drive the balloons at from seven to eight miles per hour, which would be quite sufficient as a *first* experiment.

As men have the choice of time, in a great degree, those winds that are tolerably favourable to any intended voyage, can often be selected; different current in the air can also be occasionally met with, so that balloons offer more advantages from the wind, than inconvenience from its occasionally being too strongly against their line of sailing.

I have been applied to by an ingenious foreign mechanic, now in Rome, who affirms, that by a particular apparatus of his own, he has guided small balloons with considerable velocity; that he is in possession of an engine four-times more energetic, weight for weight, than the lightest of our steam-engines (the powers of which I gave him, as stated in this letter), and that he wishes much to exhibit the proof of what he says, in London, should he meet with any persons who would pay the expenses of his journey; previous to which, he offers to satisfy any of the British residents in Rome that he can perform what he asserts. Should a good subscription-purse be obtained for general ballooning purposes, it may be just and desirable to give this humble workman an opportunity of substantiating his claims, by thus previously exhibiting his machine to the celebratep artists, Mr. Gibson and Mr. Macdonald, or other well-known British residents in Rome. For my own part, I shall be ready to become a subscriber to any rational plan for trying experiments upon balloons on truly scientific principles, and free from any *jobbing* or *exhibition*-making speculations.

Let the friends of aerial navigation be called together by advertisement in your pages, at the instigation of a few names favourable to the project; let a place—say the Adelaide Gallery, if the proprietors permit it — and some convenient day in next month, be named; and from this meeting let such resolutions emanate, as may best ensure the progress of *The Society for Promoting Aerial Navigation.*

I am, Sir,

Your obliged and obedient servant,

George Cayley.

Forwarded Jan. 23, 1837.

AEROSTATION.

Sir,—My thanks are due to Mr Lake, for the pains he has taken to correct an error into which it appears I had fallen, in an article published in your 637th Number, on the practicability of guiding and directing air-balloons. I know it is usual occasionally when a palpable blunder appears, to take shelter behind the *printer's devil*, by representing it as a typographical error; however, on the present occasion, I have no desire to interpose this shield, but will readily admit that it might possibly have been so stated in the manuscript, although with Mr. Lake, I cannot "imagine how I could make so great a mistake in so simple a calculation." A mistake it certainly is ; and as Mr. Lake, I dare say, will readily allow me the credit of the blunder, I am willing to repay his courtesy by conceding to him the honour of having corrected it. Mr. Lake thinks it seems that the strength of a hundred eagles or so, would be as nothing if applied to overcome the great resistance opposed to the progress of a balloon against the wind, but thinks that great power might be gained from an air-pump. Well, if Mr. Lake likes the air-pump better, I have no objection. But afterwards, seeming to forget himself, he breaks out into the grandiloquent style and says, "we see the eagle possessed of *power*, not merely sufficient to raise its ponderous body from the earth, but also giving it a velocity outstripping the wings of the wind." Therefore, says Mr. Lake, eagles would be of no use whatever.

Farther on he says, "the effect (that is of the aforesaid air-pump) would be so certain, and the means of applying it so simple and easy, as to leave comparison with any method already known out of the question." Those who understand the subject, will not be disposed to entertain any doubts as to the effect, I believe, looking at the means proposed; but "the effect" would be of a very dif-

ferent description to that which Mr. Lake seems to anticipate. In the conclusion of his letter he says, alluding to *his* plan, "I am sure your readers must acknowledge its *simplicity.*" Here I agree with Mr. Lake, I think they *must.*

I am, Sir, &c.

T. S. MACKINTOSH.

CASE IN TURNING.

Sir,—I send you the following answer to H. F. H., p. 249. The common length of band will be 109·82 inches; the diameters of the two circles required will be 24·036 and 22·025.

Solution.

1st groove on pulley 3 inches diameter	4·71	inches semi-circumference.	
Circle to correspond, 26 inches	40·85	do.	do.
Length of band between the centres	64·26	do.	do.
	109 82		
2d groove on pulley, 5 inches diameter	8·64	do.	do.
Circle to correspond, 24·36 inches	38 28	do.	do.
Band between centres	62·90	do.	do.
	109 82		
3d groove on pulley, 8 inches diameter	12·57	do.	do.
Circle to correspond, 22·26 inches	38 49	do.	do.
Band between centres	61 76	do.	do.
	109·82		

The above is sufficiently correct for practice; but the band will be slack when on the 3-inch pulley, because the band goes off in a tangent before it leaves the horizontal axes.

Yours, with respect, WILLIAM ANDREWS.

Ivinghoe, Bucks, Jan. 10, 1836.

N. B.—I answered a similar question in vol. ix., proposed in vol. viii. p. 231.

M'CULLOCH'S STATISTICAL ACCOUNT OF THE BRITISH EMPIRE.

Every body has heard of the startling remark of Sir Robert Walpole, when his son proposed to read history to him in his retirement, "Any thing but history, for that *must* be false." Something similar might well be the exclamation of the searcher for a true knowledge of the state of things from the imposing columns of figures in official returns—"any thing but statistics, for they *must* be incorrect." Look at the population returns, for instance, which form the grand magazine of facts to which the statistician has access. However valuable they may appear in the aggregate, it is notorious that no one can inspect those parts of them which relate to any district or neighbourhood with which he may happen to be well acquainted, without discovering a multitude of errors and misrepresentations (however occurring), quite sufficient to mislead any one who might be compelled, by want of the requisite local knowledge, to place a full reliance on their accuracy. The sources of mistake are necessarily extremely numerous, but they are multiplied to an immense extent by the wider range which the census returns have lately—especially on the last enumeration—attempted to take; by the minuter subdivisions which have been introduced, with the *intention* of procuring materials for a correct estimate of the condition of the people, as well as

their numbers, but with the *effect* of puzzling the matter more than if the details sought had been still left to the vague conjecture of individuals.

Notwithstanding these drawbacks, however, of whose importance he seems to be pretty well aware, Mr. M'Culloch, the well-known lecturer on Political Economy, and author of the "Dictionary of Commerce," and several other works of the same complexion, has thought the present a fit and proper time for putting forth a new "Statistical Survey of the British Empire."* It must be acknowledged that a standard work on the condition of the United Kingdom has been for a long time one of the most crying of our literary desiderata,—but we are by no means so well satisfied that the method adopted by Mr. M'Culloch is the proper one for filling up the vacuum so completely as it ought to be. After remarking in his preface, that the work of Chamberlayne, published in the reign of George the Second, was the last of the kind of any authority, he goes on to observe, that "during the long interval between Sir William Petty and Dr. Beeke, statistical science could scarcely be said to exist," but that, much information having been given in the Censuses of 1821 and 1832, and in the recent Reports of Parliamentary Committees and Crown Commissioners, "the time seemed to be at length arrived when it might be attempted to compile a work that should give a pretty fair representation of the present condition of the United Kingdom." Here we join issue. The grand work that is to take its place as *the* standard Picture of Great Britain will derive a good deal of assistance, of course, from the (too) large accumulation of raw material contained in the Parliamentary Reports, but its foundation must be laid on the basis of ORIGINAL RESEARCH, and not a stone used in the superstructure from the mass so temptingly at hand, until its trustworthiness has been tested by actual experiment. In other words, the authors of such a work must see with their own eyes, and make use of the population and other returns only so far as they tally with the results of actual observation. Mr. M'Culloch, it will be seen, does not think this troublesome process necessary. His work is entirely and altogether a compilation—a book made up of scraps from other books, without the writer's troubling himself to walk half-a-dozen steps from his library to ascertain from a peep at the out-of-doors-world whether any feature of the picture he was drawing of it was like or no: in short, a book where every thing is taken upon trust, and no addition made to the general stock of information. It is not a work so got up that will definitively fill up the "aching void" which is generally admitted to exist.

The plan followed is nearly the same as that of Peuchet, in his "*Statistique Elementaire de la France*," relieved a little of its excessive dryness,—for, strange to say, on dry subjects our usually lively neighbours approach to the proverbial aridity of "a lime-burner's basket." Our author says on this head,—

"We have not been satisfied, for example, in giving an account of any branch of industry, with stating the value of its products, the number and wages of the people engaged in it, and so forth; but have, in addition, given some notices of its history, and of the more prominent circumstances that have accelerated or retarded its progress. This seemed to be necessary to impart interest to the work, to make it useful, and *to give it a chance for getting into circulation*."

A rather strange confession to be made by a statistician,—a dealer in nothing but mere figures, amounting, as it does, to an admission that his own peculiar department is without either interest or utility, and (which is most to the point, and doubtless true enough,) without *saleability*. Most readers will be perfectly ready to concur in the whole of this candid estimate of the value of bare "statistical science," *per se*.

The work opens with a general view of the "Extent, Physical Circumstances, and Civil Divisions of the British Empire;" the first chapter, subdivided into various sections, being devoted to England and Wales. This geographical portion is well executed, and appears to be a sort of abridgment of that part of the "Library of Useful Knowledge" devoted to "Physical Geography"—a subject on which many numbers of that series have recently appeared. Nor is

* A Statistical Account of the British Empire, exhibiting its Extent, Physical Capacities, Population, Industry, and Civil and Religious Institutions. By J. R. M'Culloch, Esq. Assisted by numerous Contributors. In 2 vols. London, 1837. C. Knight and Co. 8vo., pp. 642—700.

this the only part of the work in something like the same predicament: no small quantity of the remainder of its contents having appeared at one time or other in some of the multifarious periodicals issued by the Society, especially in the *Penny Cyclopædia.* Of course this matter is dovetailed in here by the Society's consent, as we are informed in the preface, that, although edited solely by Mr. M'Culloch, it is published with the sanction, and, we believe (for the point is left in a rather obscure state), at the expense of the ex-Chancellor's "literary club." For the general part of this introductory chapter we are indebted to the editor himself—the sections which follow, on the Geology, Climate, Botany, and Zoology of England and Wales, are respectively contributed by Mr. R. Bakewell, Dr. Copland, Sir William Jackson Hooker, and Mr. Swainson: each of these is good of its kind, but being the production of hands working independently of each other, they do not perhaps combine so well as might be wished to form a harmonious whole: they have too much the air of separate essays, rather than parts of the same work; though this is by no means offensively apparent. The "Statistical Sketches of the English Counties," which succeed to the general view, are too short to allow of any thing more than a very meagre outline of the capacities and characteristics of each; and even this, so far as it is founded on statistical authorities, is too often of a misleading nature. Thus, under the head Herts, after a tolerable, but too short topographical sketch, we are informed that the largest town in the county is Hemel Hempstead, which is represented as far exceeding even the county-town in population. This is one of the many instances of error produced by the population returns. The town in question is, in fact, a small and unimportant one, far exceeded in every respect not only by Hertford, but by St. Alban's, which is not noticed at all in this "Statistical Survey," and many others; it happens, however, to have a very large extent of rural district parochially attached to it, and, the census returns being made from the parishes, the numbers of the country population (exceeding by three or four times that of the town *proper*) go to swell up Hemel Hempstead to the dimensions of a "town of the first importance;" while St. Alban's, being split into several parishes, with no rural district at all, is left out altogether. There are numberless such instances as this, some of which are indeed noticed by Mr. M'Culloch himself; and such being the case with the simple enumeration of the people, what reliance can be placed on these same returns when they relate to matters so much more recondite, as their ages, occupations, &c. We happen to know that a certain parish in the suburbs of London, which is entirely covered by houses, flourishes in the returns as finding agricultural employment for 47 families, while its next neighbour countrywards, which is of infinitely greater extent, is built on only in a small proportion, and contains a number of farms, besides "numbers without number" of market gardens, nurseries, pleasure-grounds, &c &c., is made to support only 19 families of the same description! In fact, without some means of correction by local knowledge, the population returns are merely "blind leaders of the blind;"—those who make use of their guidance had need to keep their own eyes wide open into the bargain.

To "England and Wales" succeed similar notices of "Scotland" and "Ireland." Part II. is devoted to a summary of the various population returns, chiefly in the "dry bones" form of figures alone; and Part III., which is the most copious of all, relates to that widely-ramifying subject, the "Industry" of the British empire, commencing with Agriculture, from which we pass on, through Mines, Minerals, and Fisheries, to the almost inexhaustible subject of "Manufactures," on which Mr. M'Culloch is much more elaborate than on any of the preceding divisions. After a general sketch of the "Circumstances favourable to Manufactures" in this country, he proceeds, in the style indicated by the short extract we have quoted from the Preface, to devote a section each to the Woollen, Cotton, Linen, and Silk Manufactures, one to Hardware, Watches, Jewellery, &c., another to Manufactures in Leather, one to Earthenware and Glass, and one to Paper; the whole winding up with a section on that gigantic subject of Breweries and Distilleries, and a second on Miscellaneous Productions, Hats, Soap, Sugar, &c. Each of these articles contains a good deal of in-

formation, although, of course, most of the matter is by no means startling for its novelty. As a specimen of Mr. M'Culloch's manner of handling this extensive portion of his plan, we extract nearly the whole of his history of the Earthenware Manufacture, which we have selected principally because its dimensions are of rather a more manageable nature than those of the necessarily more lengthy articles on the Woollen and Cotton Manufactures. The subject, neverthelesss, is in itself by no means deficient in interest:—

"The manufacture of earthenware, or, as it is frequently called, stoneware, is of very considerable importance. It is carried on in several parts of the country; but its principal seat is in the district called, by way of distinction, the 'Potteries,' in the north-west part of Staffordshire. It is doubtful when the manufacture was originally established here; but it has certainly been prosecuted at Burslem for the last two centuries. Dr. Plot, whose 'Natural History of Staffordshire' was published in 1686, gives what is believed to have been a very accurate account of the manufacture at that time. The wares were then of the coarsest and commonest sort, and consisted principally of pots for the preservation of butter, whence Burslem is, in several old maps, marked with the appellation of 'Butter Pottery!' Plot says that the wares were 'chiefly sold to the poor crate-men, who carried them at their backs all over the country!' About the year 1690, some improvements were introduced into the manufacture by two foreigners of the name of Ellers. Superior clays were also brought from Dorset and Devonshire; and the fabric of the ware was improved by the addition of pounded flints, &c. Still, however, British earthenware was very inferior in beauty to that of France, which was, consequently, imported in considerable quantities, and was almost the only thing made use of by the more opulent class of customers.

"It was not till about the year 1760, or 1762, that the grand era of improvement commenced in the potteries. We are indebted for it to the exertions and example of Mr. Josiah Wedgwood, who did for the manufacture of earthenware what Arkwright did for that of cotton. This eminent individual was the youngest son of a potter, was very indifferently educated, and received but little property from his father. But these untoward circumstances, far from repressing, served rather to stimulate the native vigour of his mind. His original and inventive genius enabled him to make many important discoveries; while his practical acquaintance with the business gave him the means of successfully introducing them into practice. Besides improving the composition, the glaze, and the colours of the old wares, he invented several that were altogether new; and (which was least to be expected from a person in his situation) he made vast improvements upon the figure of the articles manufactured, displaying in their formation a degree of classical elegance, and purity of design, which materially improved the national taste, and has never been surpassed. In addition to this, Mr. Wedgwood successfully exerted himself to improve the communications with the potteries; and was mainly instrumental in carrying the Act for the Trent and Mersey Canal through Parliament, and in accomplishing that grand undertaking. The village of Etruria, where his works were situated, was built by him. Since his death, which took place in 1795, they have been carried on by his descendants.

"The inventions and discoveries of Mr. Wedgwood were soon universally introduced, and the manufacture has since continued gradually to extend and to improve. Its progress, we are assured, has been such, that a workman of the present day can, in a given time, produce about *four* times the quantity of manufactured articles he could have done in 1790!

"Exclusive of earthenware, china-ware is also extensively manufactured in the pottery district. It is estimated that the value of the various sorts of earthenware produced at the potteries may amount to about 1,500,000*l.* or 1,600,000*l.* a year, and that the earthenware produced at Worcester, Derby, and other parts of the country, may amount to about 750,000*l.* more; making the whole value of the manufacture 2,250,000*l.* or 2,350,000*l.* a year. The consumption of gold for gilding, &c. at the potteries, is about 650*l.* a week, and of coal about 8000 tons a week.

"The finer sorts of clay used in the potteries are principally brought from the Isle of Purbeck, in Dorsetshire, and from Devonshire; stealites, or soap-stone, is brought from Cornwall, large quantities of flints from Kent, and some from Wales, Ireland, &c. The canals by which Staffordshire is intersected, and which unite the potteries with all the principal ports of the kingdom, afford the greatest facilities for the conveyance of the raw materials used in the manufacture, and for the easy distribution of the wares to the great markets at home and abroad.

"The population of the pottery district, which is naturally poor and barren, is exceedingly dense. It comprises from 60,000 to 70,000 inhabitants. The principal places are Burslem, Shelton, Longton, Stoke-upon-Trent, Henley, Lunstell, Lane-End, Etruria,